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ICE CONSTRUCTION - PROTOTYPE SUBMERSIBLE ELECTRIC PUMP AND EXTENSION TUBE

BY

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ICE CONSTRUCTION - PROTOTYPE SUBMERSIBLE

ELECTRIC PUMP AND EXTENSION TUBE

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ABSTRACT

Sea ice has been used extensively in polar regions for roads, runways, camp sites and other operational purposes. It has been found, through field experiments, that free flooding ice at sub-freezing temperatures is an effective method of improving the surface and load bearing capacity of natural ice sheets. In this technique, water is pumped from below the ice, discharged around the pump, and allowed to seek its own level.

The successful performance of an experimental submersible electric pump in this application at Thule, Greenland, led to the design and fabrication of a prototype casing and extension tube for high-volume, low-lift pumps. Functional testing of a 1,600-gpm, 12-foot-head prototype in the Port Hueneme harbor indicated that it should be well suited for flooding natural ice surfaces from 1 to 30 feet or more in thickness. Following correction of the corrosion and electrical connection problems encountered in the Hueneme tests, the unit will be tested in a polar environment.

INTRODUCTION

Operational requirements in polar regions frequently include the use of natural floating ice surfaces for roadways, runways and other facilities. Flooding these surfaces in below-freezing temperatures has been found to be an effective method of increasing ice thickness for greater strength and improved surface characteristics.

This technical note presents the design, fabrication and functional testing of a 1,600-gpm prototype submersible electric-driven pump for flooding ice.

BACKGROUND

Ice-flooding experiments in Alaska in 1951 and 1952[1] showed the feasibility of improving natural ice sheets by surface flooding. Additional work in 1958-59 and 1959-60[2,3,4] resulted in an evaluation of flooding techniques, a study of ice properties and saline brine migration in the flood zone, and the development of engine-driven centrifugal pumps for fixed and mobile use.

The mobile pumps developed for location outside the flood zone with hose or pipeline distribution of water included a self-contained pump wanigan[5] and a high-mobility skid-mounted pumping unit.[6] The pump wanigan, which weighed 16,000 pounds, contained a 1,000-gpm, 65-psi centrifugal pump driven by a 48-hp diesel engine. Hose and other accessories for independent operation were also included. The ski-mounted pump with weathertight enclosure, which weighed 3,700 pounds, consisted only of a winterized 500-gpm, 80-psi centrifugal pump driven by a 50-hp diesel engine.

A high-volume centrifugal pump for fixed elevated installation within the flood zone was also developed for the Point Barrow trials.[6] This unit, which weighed 2,900 pounds, consisted of a 45-hp diesel-engine-driven centrifugal pump delivering a maximum of 1,800 gpm at 15 psi. It was elevated above the flood zone on columns frozen into the ice and housed in a field-fabricated enclosure. Mechanical operation of the pump was satisfactory; however, the unit had several

inherent disadvantages when used in fixed elevated installations. These included:

1. Elevation of the heavy pump required a rugged support structure and heavy lifting equipment.

2. Maintenance and servicing of the engine was more difficult because of the elevated position.

3. Pump priming was more difficult because of the higher suction lift.

Disadvantages of the elevated diesel-engine-driven pump led to the development of an experimental high-volume, 16-foot-long, submersible electric-driven pump for fixed installations.[7] This 7.5-hp unit operated from a 15-kw generator and delivered 1,600 gpm at 12-foot head.

Field tests on the unit were conducted on North Star Bay near Thule, Greenland, in the winter of 1959-60.[8] In these tests, the pump was frozen into and extended through the floating ice sheet near the center of the flood zone. Water was drawn from below the ice and discharged onto the surface as a geyser. Results of this work showed the pump to be exceptionally well adapted to this technique of ice construction.

Based on success of the experimental pump, a prototype submersible unit was designed which would accommodate either an 800- or 1,600-gpm, 25-foot-head pump and motor. A prototype pump unit and an 8-foot casing extension tube were fabricated and functionally tested in the Port Hueneme harbor in early 1965.

DESCRIPTION

The prototype submersible electric pump (Figure 1) consists of two bolt-together sections. The lower section containing the pump and electric motor is complete in itself and may be used independently in ice from 1 to 5 feet thick. The upper section is a typical extension unit for increasing the length of the water discharge and outer casing. One or more of these may be added to the pump section for use in floating ice up to 30 feet or more in thickness. Extension sections are also used for extending the discharge tube as flooding progresses and ice builds up around the casing.

Freezing of water in the discharge tube during periods of non-use is prevented in both sections by sealing the top of the tube and displacing the water with compressed air. A secondary system of electric heating elements is provided for clearing the discharge tube should pressure be lost and freezing occur.

Construction of the two sections is similar with many components common to both. Aluminum is used throughout for reduced weight.

Pump Section

The pump section (Figure 2) is 93 inches long, 20 inches in diameter and weighs 630 pounds. The pump and motor assembly is located at the bottom of the 1/8-inch-thick aluminum outer casing. A cone-shaped transition directly above the motor, funnels the water flow into a 6-inch aluminum discharge tube concentric to the outer casing. This tube extends above the top of the outer casing a..d terminates in a cam-locking fitting. Eight threaded bolt holes are spaced around the top of the unit to provide for attachment of the extension section.

Two electric hea'ing systems composed of curved segmented resistance elements are used in the pump unit. One system applied to the inner surface of the 20-inch casing melts ice from around the casing to facilitate pump removal. The other is applied to the discharge tube to melt ice should the primary freeze prevention method fail. Elictrical power cables for the pump motor and two heater circuits terminate in male weathertight connectors at the top of the unit.

The space between the 6-inch discharge tube and the 20-inch casing is filled with rigid urethane insulation foamed in place. This closed-cell material, with 20-psi compressive strength and temperature stability to 300°F, insulates the back side of two heating circuits, stiffens the thin metal outer casing, and encapsulates the interior components to prevent water damag. should leaks develop.

The pump section is designed to accommodate either an 800- or 1,600-gpm, 25-foot-head pump and motor assembly. Pump and motor assemblies of other capacities may be used with appropriate adaptors if the motor is no more than 15.5 inches in diameter nor more than 25 inches high above the adaptor.

Extension Section

The pump extension section (Figure 3) is 93 inches long, 20 inches in diameter and weighs 330 pounds. The lower end of open design mates with the pump section and contains electrical connectors for extending the heating system and pump power cables. When assembled, curved aluminum panels connect over the open area with flush fastenings to maintain a continuous smooth exterior surface and to conduct heat from adjoining areas for pump removal. The top of the extension section is identical to the top of the pump section so that additional extensions can be joined as required. Electric heating systems and urethane insulation similar to that in the pump section are also provided.

TESTS

Following fabrication in the laboratory shops, the pump and extension units were functionally tested in the harbor at Port Hueneme. The propeller pump and submersible electric motor assembly used in the prototype was the same as that used successfully in the experimental submersible flooding pump. This assembly met all requirements of the 1,600-gpm prototype except for a discharge head of 12 feet rather than the specified 25 feet. This difference was not significant in the harbor tests on the prototype unit, which were made to determine:

1. Adequacy of the mechanical connection between pump and extension section.

2. Suitability of submerged electrical connections.

3. Resistance to corrosion in a marine environment.

4. Ease of handling and general operational suitability.

Immediately after installation, electrical power was connected to the pump and the unit operated for approximately 30 minutes. Thereafter, the pump was operated for short periods about every 7 days during a 32-day emersion period. A change in pump location was required twice during this period, the first following collision with a barge and the second to obtain protection from excessive wave action. In addition to operating the pump during the test period, checks were made on the [illegible] electric heating circuits and the tightness of the water disc[illegible] ube connection between pump and extension section.

OBSERVATIONS

During installation, it was found that the 960-pound, 16-foot-long pump and extension assembly had a natural buoyancy that results in about 4 feet of the unit extending above the surface.

The only difficulty encountered in operating the pump occurred during the third week following exposure to heavy wave action and impact between the top of the pump and the underside of the dock to which it was secured. This difficulty was electrical in nature and resulted in pump shutdown after a short period of operation due to tripped circuit breakers. Examination after the 32-day test period showed that moisture had entered the electrical connector joining the power cable between pump and extension sections. This resulted in a low resistance short and carbonizing of the insulating material between the pin connectors (Figure 4). Entrance of water appeared to be through the O-ring seal between the male and female sections of the connectors.

Water also entered one of the two electrical connections on the heater circuits (Figure 5). Damage was not as extensive as in the pump connector since the circuit had not been energized subsequent to leakage.

Extensive corrosion was found in two areas where cast aluminum components were used. Figure 6 shows the heavy, scaley growth of corrosion products on the 6-inch discharge-tube couplings between the pump and extension sections. The other area of corrosion was less critical, having affected only the 1-inch cast aluminum pipe plugs used to close holes through which the urethane foam had been injected. One of these plugs is visible in Figure 7.

In the 32-day period, corrosion progressed sufficiently so that the 6-inch discharge fittings broke from their respective tube sections when disassembled. The remains of the socket-weld base of the fitting may be seen in Figure 7. Figure 8 shows a section of the male and female fittings and gasket. Examination of the parts showed a combination of galvanic and stress corrosion. The galvanic cell developed between the 6061-T6 aluminum tube and the cast aluminum fitting of undetermined alloy, with the latter serving as the anode. Stress corrosion occurred in the socket-weld portion of the fitting because of failure to weld the joint both inside and out during fabrication. The resultant crack on the inside provided an excellent area for

corrosion and accompanying high stress. An identical cast fitting on the top of the extension section showed little sign of corrosion because it was in the splash zone rather than totally submerged.

FINDINGS

1. The sectionalized design of the prototype unit into a pump section and extension sections increases the versatility of the submersible electric pump for ice construction because:

a. The reduction in weight and length of individual sections simplifies handling and installation.

b. Extension sections permit and pump to be adapted to ice of varying thickness.

2. Mechanical connection between sections is satisfactory, but corrosion and failure of electrical fittings require the following modifications to the prototype design:

a. Cast aluminum fittings should be eliminated or protective coated to prevent galvanic corrosion.

b. Exposed crevices in welded assemblies should be eliminated to avoid stress corrosion failures.

c. Improved assembly of electrical connections is required to prevent entry of moisture.

3. Foam-in-place urethane between the casing and discharge tube permits the use of lighter metal sections and prevents possible water leakage to heating elements.

CONCLUSIONS

1. The prototype submersible electric pump is a versatile, easily handled unit which appears well suited for ice construction.

2. The pump and extension sections provide a high degree of flexibility in application as they will permit pump installations in floating ice from 1 foot to 30 feet or more in thickness.

FUTURE PLANS

To correct the corrosion and electrical problems encountered during the Hueneme harbor tests, a change of material and specifications will be made in the prototype design. The cast aluminum fittings will be replaced with machined parts of the same alloy as adjoining parts, and the male and female electrical connector halves will be filled with silicone grease to encapsulate the electrical contacts. Silicone grease will be used because of its electrical insulating characteristics and uniform viscosity over a wide temperature range. Following these changes, the prototype will be tested in a polar environment.

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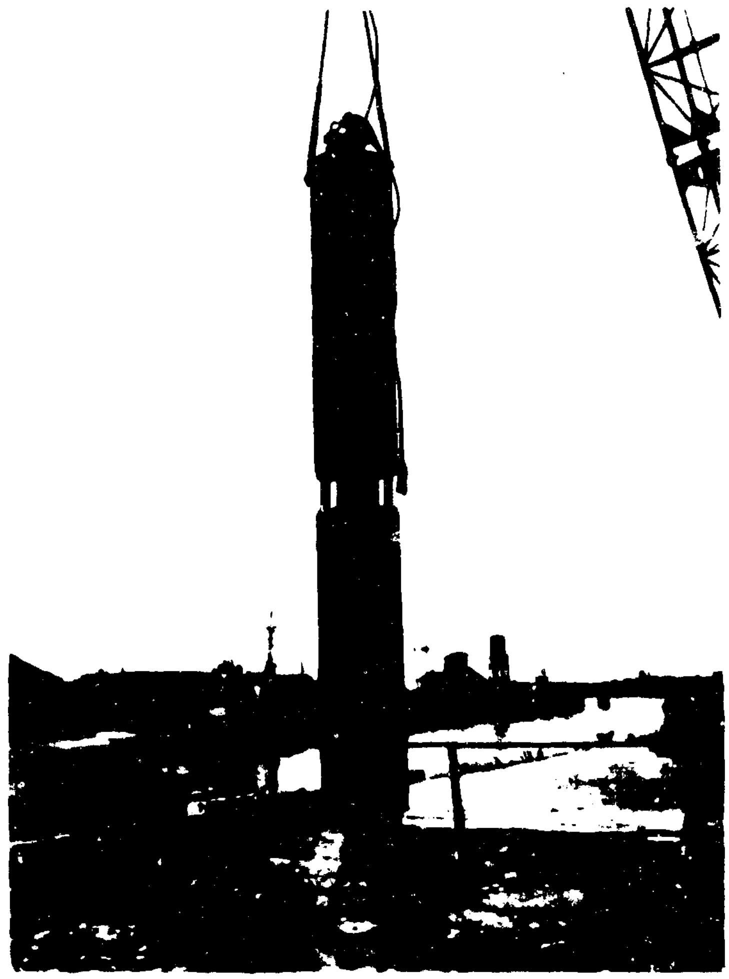

Figure 1. Prototype submersible pump and extension sections with connection cover plates removed.

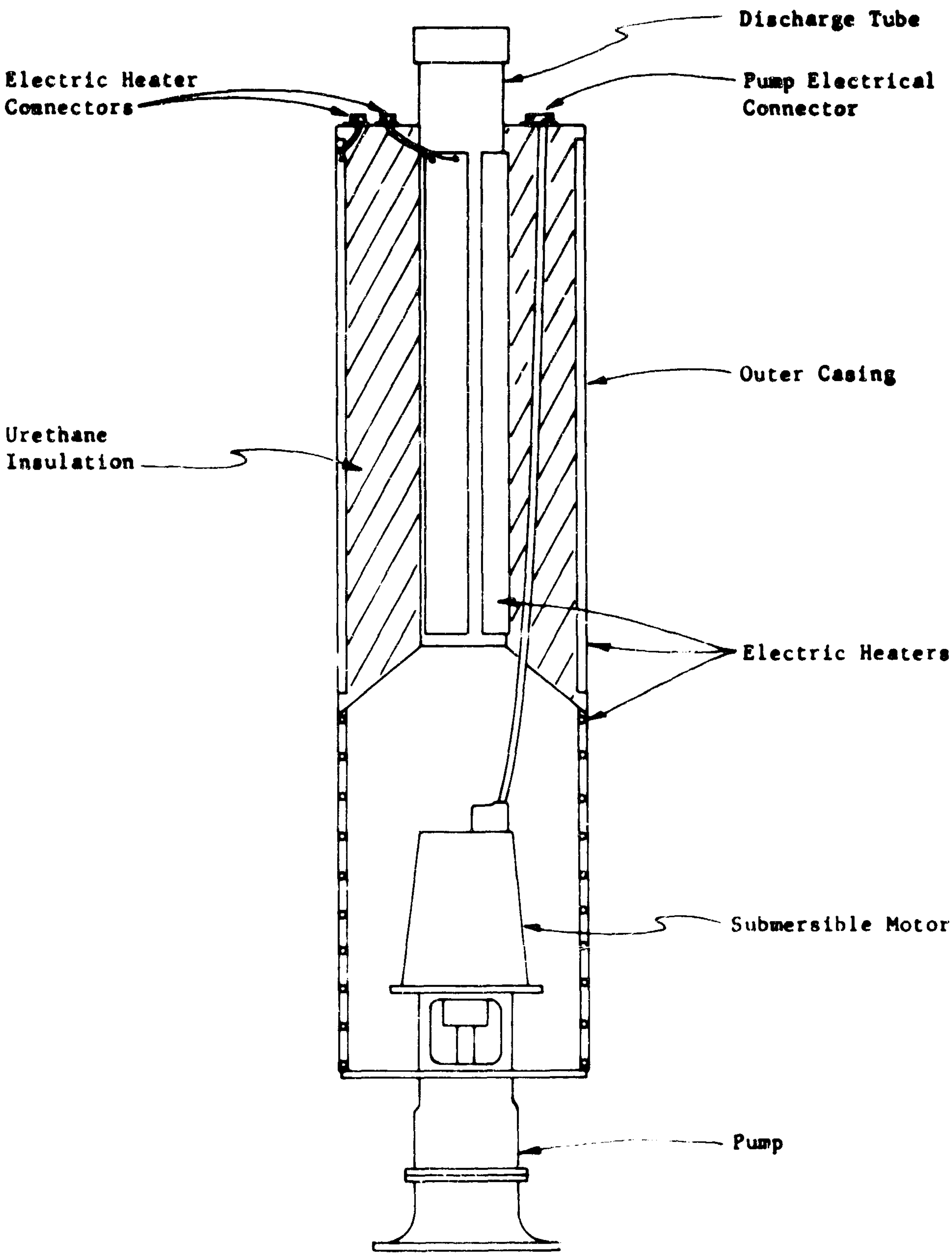

Figure 2. Pump Section Showing Location Of Components

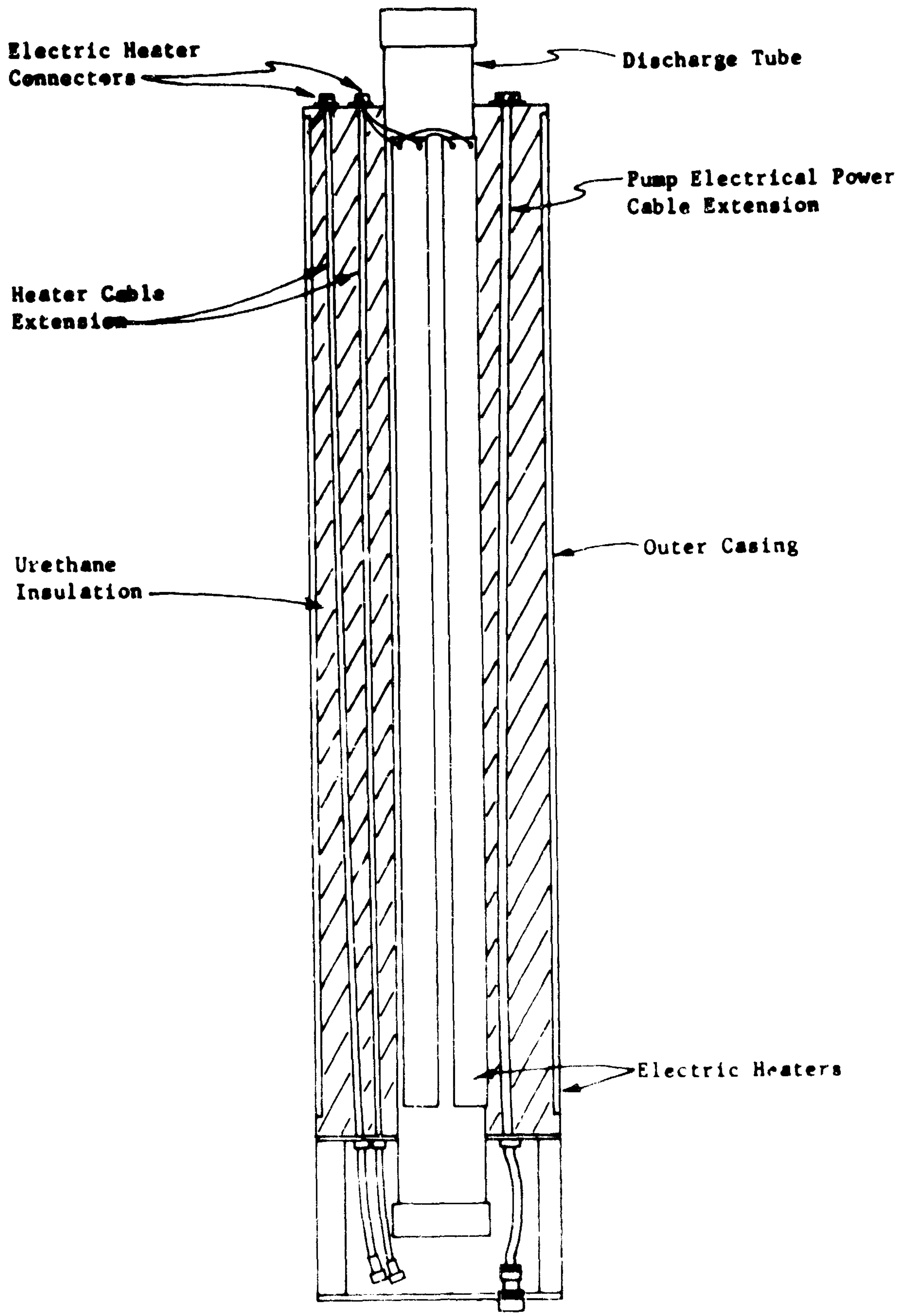

Figure 3. Extension Section Showing Location Of Components

Figure 4. Pump power cable connector shorted by moisture during Hueneme harbor tests.

Figure 5. Connectors in electrical heater circuits. Water leakage occurred in connector at right and housing (center).

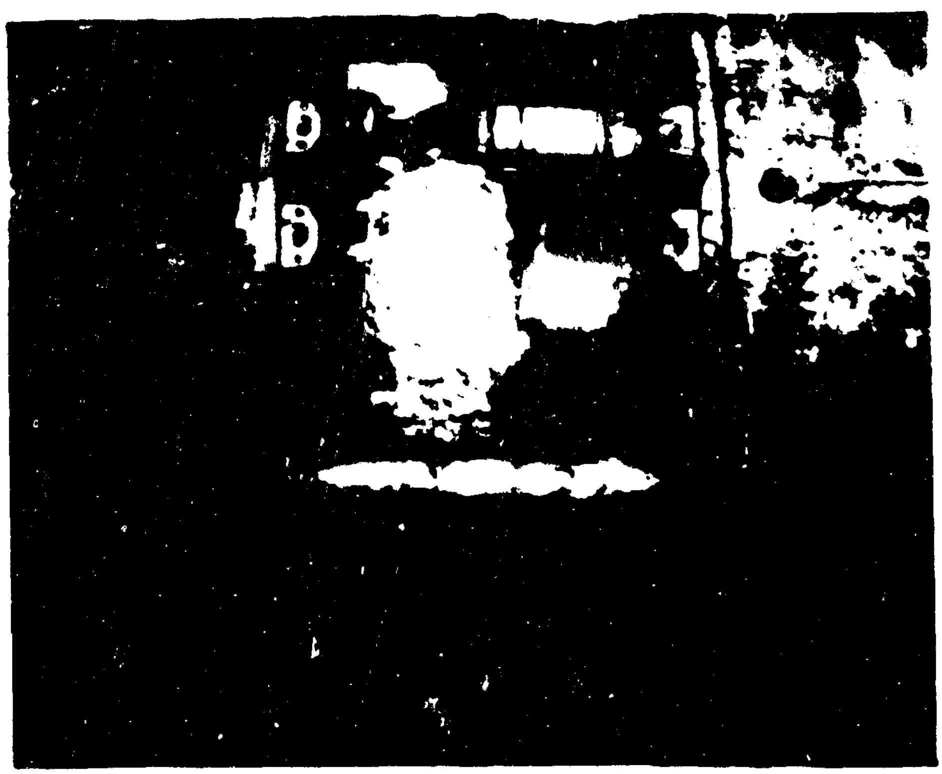

Figure 6. Corrosion on 6-inch cast aluminum fittings joining discharge tube.

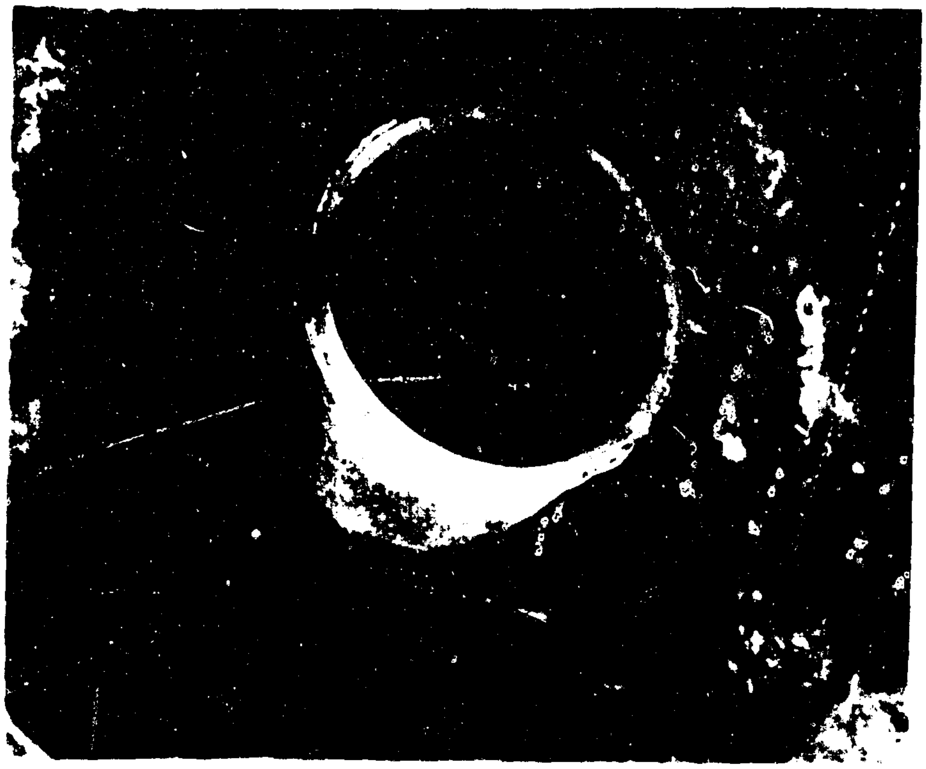

Figure 7. Top of pump section showing corroded fittings and electrical sockets.

Figure 8. Section of corroded fitting and gasket.

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Sea ice has been used extensively in polar regions for roads, runways, camp sites and other operational purposes. It has been found, through field experiments, that free flooding ice at sub-freezing temperatures is an effective method of improving the surface and load bearing capacity of natural ice sheets. In this technique, water is pumped from below the ice, discharged around the pump and allowed to seek its own level.

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